INDOOR AIR QUALITY ASSESSMENT

Fallbrook Elementary School
25 DeCicco Drive
Leominster, MA 01453

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response Indoor Air Quality Program
October 2005

Background/Introduction

At the request of the Leominster Health Department, the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at each of Leominster's public schools. These assessments were jointly coordinated through Chris Knuth, Director of the Leominster Health Department and David Wood, Facilities Director for Leominster Public Schools (LPS). On June 3, 2005, Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment at the Fallbrook Elementary School (FES), 25 DeCicco Drive, Leominster, Massachusetts.

The FES is a red brick building constructed in 1966. Five portable classrooms were added in the 1980s. Windows are openable throughout the building. The building has not been renovated; therefore, the majority of building components are original.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

Results

The FES houses grades 1 through 4, with a student population of approximately 600 and a staff of approximately 70. Tests were taken under normal operating conditions. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in four of thirty-nine areas surveyed, indicating adequate air exchange in the majority of areas surveyed on the day of the assessment. It is important to note that several areas with carbon dioxide levels below 800 ppm were sparsely populated, unoccupied and/or had windows open, which can greatly reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows shut.

Fresh air in exterior classrooms is supplied by unit ventilator (univent) systems equipped with high efficiency pleated filters (Pictures 1 and 2). A univent is designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building (Picture 3). Return air is drawn through an air intake located at the base of the unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Several univents were deactivated during the assessment (Table 1); therefore, no mechanical means to introduce fresh air existed in these areas. Obstructions to airflow, such as papers and books stored on univents and bookcases, carts and desks in front of univent returns, were seen in several classrooms (Picture 4). In order for univents to provide fresh air as designed, units must be activated and remain free of obstructions.

Exhaust ventilation in classrooms is provided by wall-mounted vents (Picture 5) powered by rooftop motors (Picture 6). Exhaust vents were either not drawing or drawing weakly in several areas (Table 1). Mr. Wood reported that two exhaust fans were on a repair list. As with the univents, a number of exhaust vents were also obstructed by desks, bookcases and other items (Picture 7). In order to function properly, exhaust vents must be activated and remain free of obstructions.

Mechanical ventilation is provided to modular classrooms by rooftop air-handling units (AHUs). Fresh air is supplied to the classroom by ceiling mounted diffusers, and air is returned to the AHUs via ceiling mounted exhaust vents. Thermostats control each heating, ventilating and air conditioning (HVAC) system and have fan settings of "on" and "automatic". During the assessment, thermostats in the modular rooms were set to the "automatic" setting. The "automatic" fan setting on the thermostat activates the HVAC system at a preset temperature. Once the preset temperature is reached, the HVAC system is deactivated. Therefore, no mechanical ventilation is provided until the thermostat re-activates the system.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a univent and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). It was reported by Mr. Wood that the LPS has a contract with Pioneer Valley Environmental, Inc., an HVAC engineering firm that conducts preventive maintenance of HVAC equipment in all of Leominster's public schools. The preventative maintenance program consists of an annual assessment of all HVAC system components (e.g., univents, AHUs, pneumatic controls, thermostats). A detailed report is generated and provided to the LPS facilities department to address needs.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 ppm. Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Indoor temperature readings the day of the assessment ranged from 75 ^{o} F to 79 ^{o} F, which were within or very close to the upper end of the MDPH comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, it is difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (e.g., univents and exhaust vents not operating and/or obstructed).

The relative humidity measurements ranged from 35 to 47 percent, which were slightly below or within the MDPH recommended comfort range the day of the assessment. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Several areas had water-stained ceiling tiles, which can indicate leaks from the roof or plumbing system. Water-damaged ceiling tiles can provide a source for mold and should be replaced after a water leak is discovered and repaired. Open seams between the sink countertop and backsplash were observed in several rooms. If not watertight, water can penetrate through the seam, causing water damage. Water penetration and chronic exposure of porous and wood-based materials can cause these materials to swell and show signs of water damage.

Several classrooms contained aquariums and terrariums. Aquariums should be properly maintained to prevent microbial/algae growth, which can emit unpleasant odors. Similarly, terrariums should be properly maintained to ensure soil does not become a source for mold growth.

Plants were noted in several classrooms, and flowering plants were seen in close proximity to univent air intakes (Picture 8). Plants can be a source of pollen and mold, which can be respiratory irritants for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from ventilation sources (e.g., air intakes, univent diffusers) to prevent the entrainment and/or aerosolization of dirt, pollen or mold.

Plants were observed growing against exterior walls (Picture 9). The growth of roots against exterior walls can bring moisture in contact with the foundation. Plant roots can eventually penetrate, leading to cracks and/or fissures in the sublevel foundation. Over time, this process can undermine the integrity of the building envelope, providing a means of water entry into the building via capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001).

A number of breaches were seen around the building exterior. Missing/damaged mortar around masonry was also observed in several areas (Picture 10). Holes, breaches, and seams are points through which water can penetrate the building, particularly under driving rain conditions. Excessive exposure of the exterior brickwork and foundation to water can result in structural damage.

Pooling water was noted on the roof due to a clogged drain (Picture 11). Freezing and thawing of water during winter months can lead to roof leaks and subsequent water penetration into the interior of the building. Pooling water can also become stagnant, which can lead to unpleasant odors and microbial growth. In addition, stagnant pools of water can serve as a breeding ground for mosquitoes.

Other IAQ Evaluations

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations ranged from 1 to 2 ppm (Table 1). Carbon monoxide levels of 1 ppm were measured in a number of areas in the school during the assessment (Table 1). This would be expected with a background reading of 1 to 2 ppm, Operating mechanical ventilation systems and/or open windows provide a pathway for pollutants from operating vehicles and busses to move into the building.

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits for particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5

standard requires outdoor air particulate levels be maintained below 65 μg/m^3 over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, the MDPH uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 23 μg/m^3 (Table 1). PM2.5 levels measured indoors ranged from 18-50 μg/m^3 (Table 1). PM2.5 measurements were below the NAAQS of 65 μg/m^3. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors. In the case of classroom C-2, occupants were cutting construction paper and working on art projects at the time of the assessment.

Indoor air quality can also be impacted by the presence of materials containing volatile organic compounds (VOCs). VOCs are substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. Outdoor air samples were taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC measurements throughout the building were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use TVOC containing products (e.g., the concentration of TVOCs within a classroom increases when the product is in use). Dry erase markers were seen in several classrooms. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). Cleaning products and air deodorizers were found under sinks and on countertops in some classrooms. Like dry erase materials, cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals.

In an effort to reduce noise from sliding chairs, tennis balls had been sliced open and placed on chair legs (Picture 12). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas TVOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998). Consideration should be given to replacing tennis balls with alternative glides (Picture 13).

Several other conditions that can affect indoor air quality were noted during the assessment. In some classrooms items were observed on windowsills, tabletops, counters, bookcases and desks (Pictures 4 and 14). The large number of items stored in classrooms provides a source for dusts to accumulate. These items (e.g., papers, folders, boxes) make it difficult for custodial staff to clean. Items should be relocated and/or be cleaned periodically to avoid excessive dust build up.

A number of exhaust/return vents and personal fans were observed with accumulated dust (Picture 15). If exhaust vents are not functioning, backdrafting can occur, which can re-aerosolize dust particles. In addition, these materials can accumulate on flat surfaces (e.g., desktops, shelving and carpets) in occupied areas and subsequently be re-aerosolized causing further irritation. Dust can be irritating to eyes, nose and the respiratory tract. Accumulated chalk dust was noted in some classrooms. Chalk dust is a fine particulate, which can be easily aerosolized and is an eye and respiratory irritant.

In one classroom, a birds' nest was observed on the univent (Picture 16). Nests can contain bacteria and may be a source of allergenic material. Nests should be stored in sealed bags to prevent aerosolization of allergenic material or discarded.

Finally, of note was the use of food as school project materials (Picture 17). Exposed food products and reused food containers can attract a variety of pests. The presence of pests inside a building can produce conditions that can degrade indoor air quality. For example, rodent infestation can result in symptoms due to materials in their wastes. Mouse urine is known to contain a protein that is a known sensitizer (US EPA, 1992). A sensitizer is a material that can produce symptoms in exposed individuals, including respiratory irritations and skin rashes. Pest attractants should be reduced/eliminated. Proper food storage is an integral component in maintaining indoor air quality. Food should be properly stored and clearly labeled. Reuse of food containers (e.g., for art projects) is not recommended since food residue adhering to the container surface may serve to attract pests.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made to improve general indoor air quality:

1. Operate all ventilation systems throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy independent of thermostat control to maximize air exchange.
2. Continue with plans to make repairs to the exhaust system.
3. Use openable windows in conjunction with mechanical ventilation to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
4. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
5. Close classroom doors to maximize air exchange.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
7. Ensure leaks are repaired and replace water damaged ceiling tiles. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.

8. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Keep plants away from the air stream of univents.
9. Clear plant growth away from the exterior of the building.
10. Inspect roof drains periodically to ensure proper drainage and prevent water pooling.
11. Contact a masonry firm or general contractor to repair breaches in exterior walls to prevent water penetration, drafts and pest entry.
12. Clean and maintain aquariums and terrariums to prevent mold growth and associated odors.
13. Seal areas around sinks to prevent water-damage to the interior of cabinets and adjacent wallboard.
14. Relocate or consider reducing the amount of materials stored in classrooms to allow for more thorough cleaning. Clean items regularly with a wet cloth or sponge to prevent excessive dust build-up.
15. Clean accumulated dust from exhaust vents and blades of personal fans.
16. Clean chalkboard/dry erase marker trays regularly to prevent the build-up of excessive chalk dust and particulates.
17. Store cleaning products properly and out of reach of students.
18. Store nests in re-sealable bags to prevent aerosolization of irritants.
19. Refrain from using food as materials for projects or seal in bag/container to prevent pest attraction.

20. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at: http://www.epa.gov/iaq/schools/index.html.

21. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/indoor_air

References

ASHRAE. 1989. Ventilation for Acceptable Indoor Air Quality. American Society of Heating, Refrigeration and Air Conditioning Engineers. ANSI/ASHRAE 62-1989

BOCA. 1993. The BOCA National Mechanical Code/1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL.

Lstiburek, J. & Brennan, T. 2001. Read This Before You Design, Build or Renovate. Building Science Corporation, Westford, MA. U.S. Department of Housing and Urban Development, Region I, Boston, MA

MDPH. 1997. Requirements to Maintain Air Quality in Indoor Skating Rinks (State Sanitary Code, Chapter XI). 105 CMR 675.000. Massachusetts Department of Public Health, Boston, MA.

NIOSH. 1997. NIOSH Alert Preventing Allergic Reactions to Natural Rubber latex in the Workplace. National Institute for Occupational Safety and Health, Atlanta, GA.

NIOSH. 1998. Latex Allergy A Prevention. National Institute for Occupational Safety and Health, Atlanta, GA.

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R 1910.1000 Table Z-1-A.

Sanford. 1999. Material Safety Data Sheet (MSDS No: 198-17). Expo® Dry Erase Markers Bullet, Chisel, and Ultra Fine Tip. Sanford Corporation, Bellwood, IL.

SBAA. 2001. Latex In the Home And Community Updated Spring 2001. Spina Bifida Association of America, Washington, DC.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.0.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 1992. Indoor Biological Pollutants. US Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, research Triangle Park, NC. EPA 600/8-91/202 January 1992

US EPA. 2000a. National Ambient Air Quality Standards (NAAQS). . US Environmental Protection Agency, Office of Air Quality Planning and Standards, Washington, DC. http://www.epa.gov/air/criteria.html.

US EPA. 2000b. Tools for Schools. Office of Air and Radiation, Office of Radiation and Indoor Air, Indoor Environments Division (6609J). EPA 402-K-95-001, Second Edition. http://www.epa.gov/iaq/schools/tools4s2.html

US EPA. 2001. "Mold Remediation in Schools and Commercial Buildings". Office of Air and Radiation, Indoor Environments Division, Washington, DC. EPA 402-K-01-001. March 2001. Available at: http://www.epa.gov/iaq/molds/mold_remediation.html

Picture 1

Classroom Univent

Picture 2

High Efficiency Pleated Air Filters in Univent

Picture 3

Univent Fresh Air Intake

Picture 4

Univent Obstructed by Items on and in Front of Unit

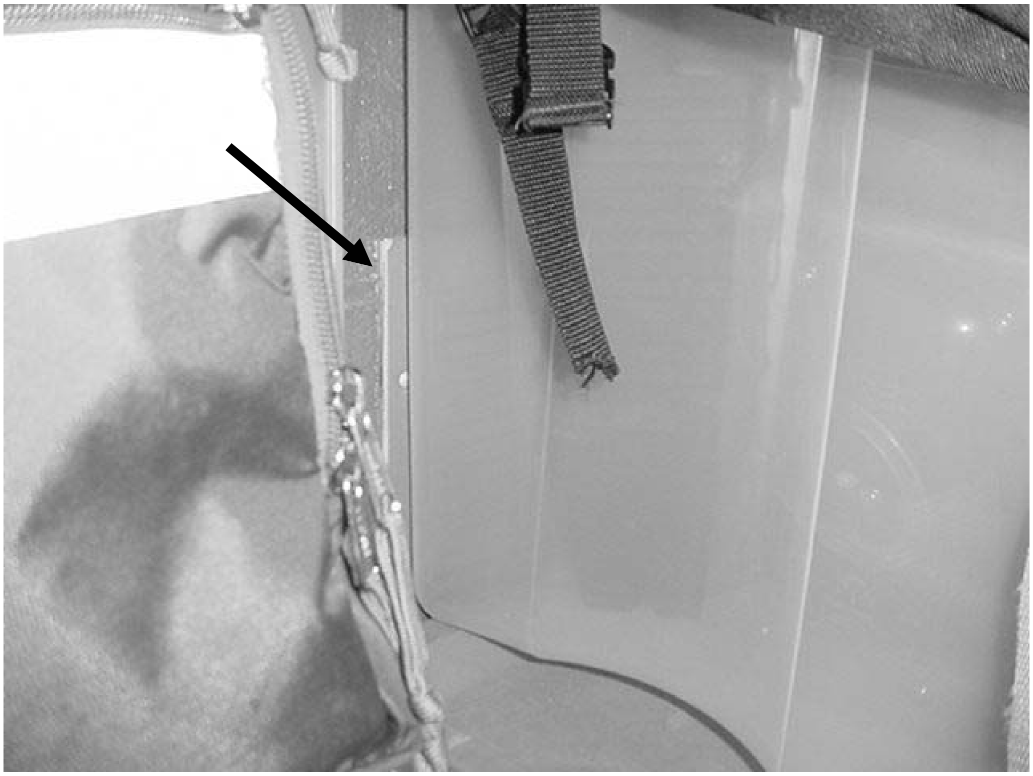
Picture 5

Wall-Mounted Exhaust Vent

Picture 6

Rooftop Exhaust Motor

Picture 7



Exhaust Vent Completely Obstructed by Plastic Tote

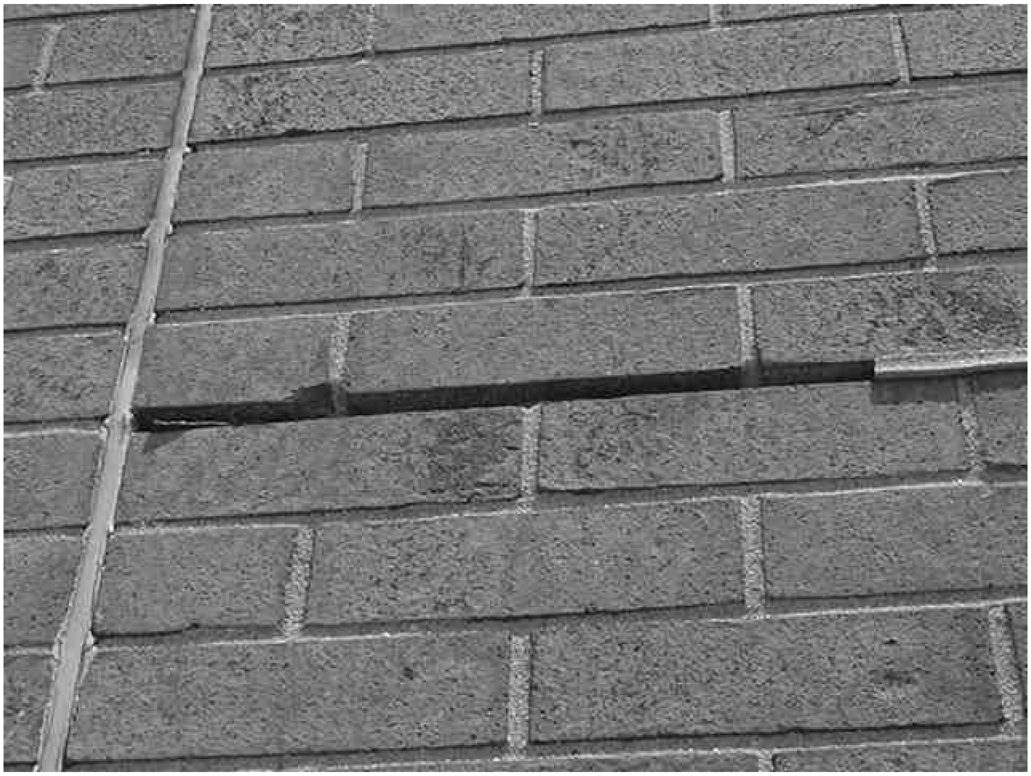
Picture 8

Plant on Univent near Air Diffuser

Picture 9

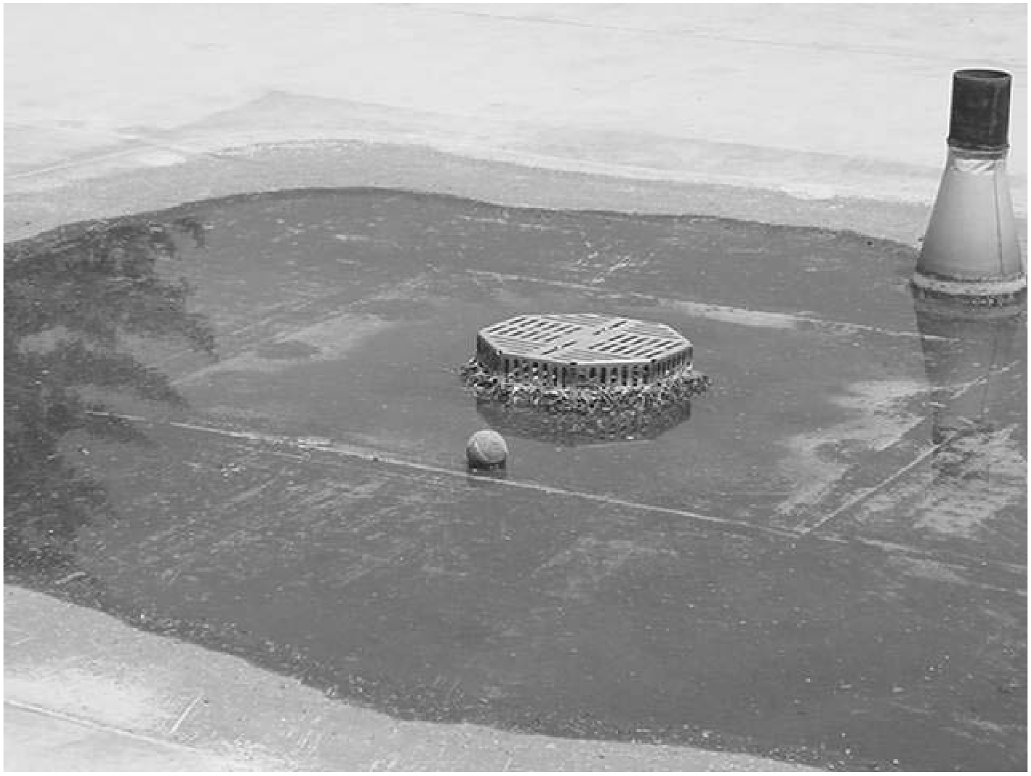
Plants/Shrubs against Exterior Brickwork

Picture 10



Missing/Damaged Mortar around Exterior Brick

Picture 11

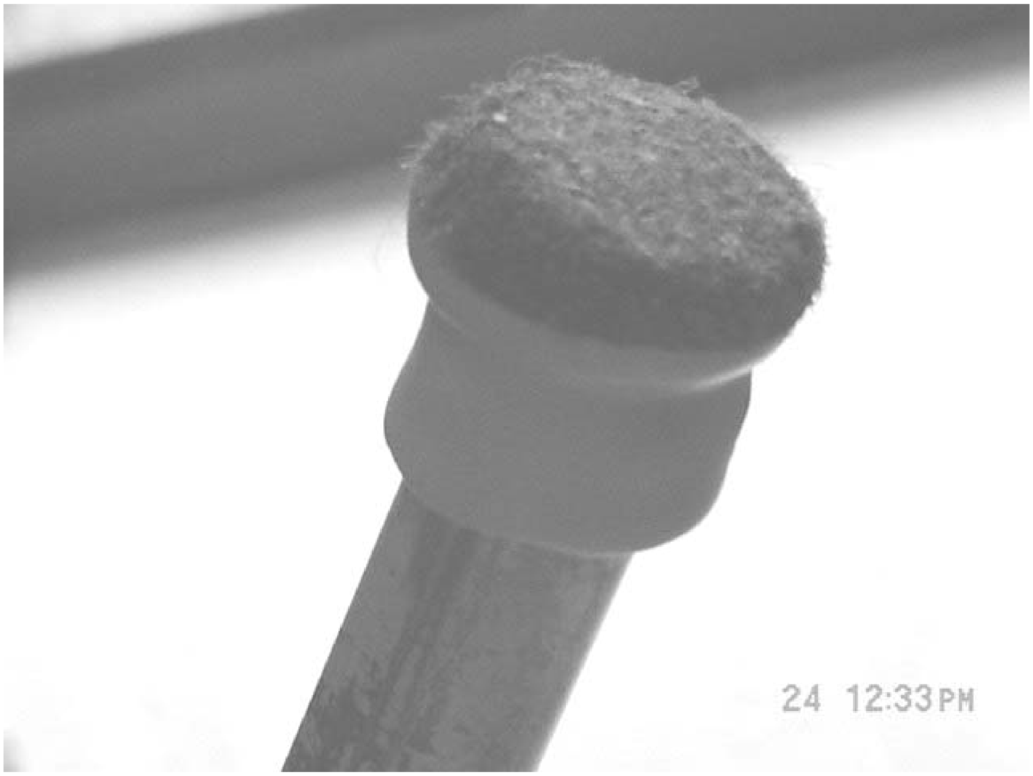


Clogged Roof Drain and Pooling Water

Picture 12

Tennis Ball on Chair Leg

Picture 13



“Glides” for Chair Legs that can be used as an Alternative to Tennis Balls

Picture 14

Accumulated Items in Classroom

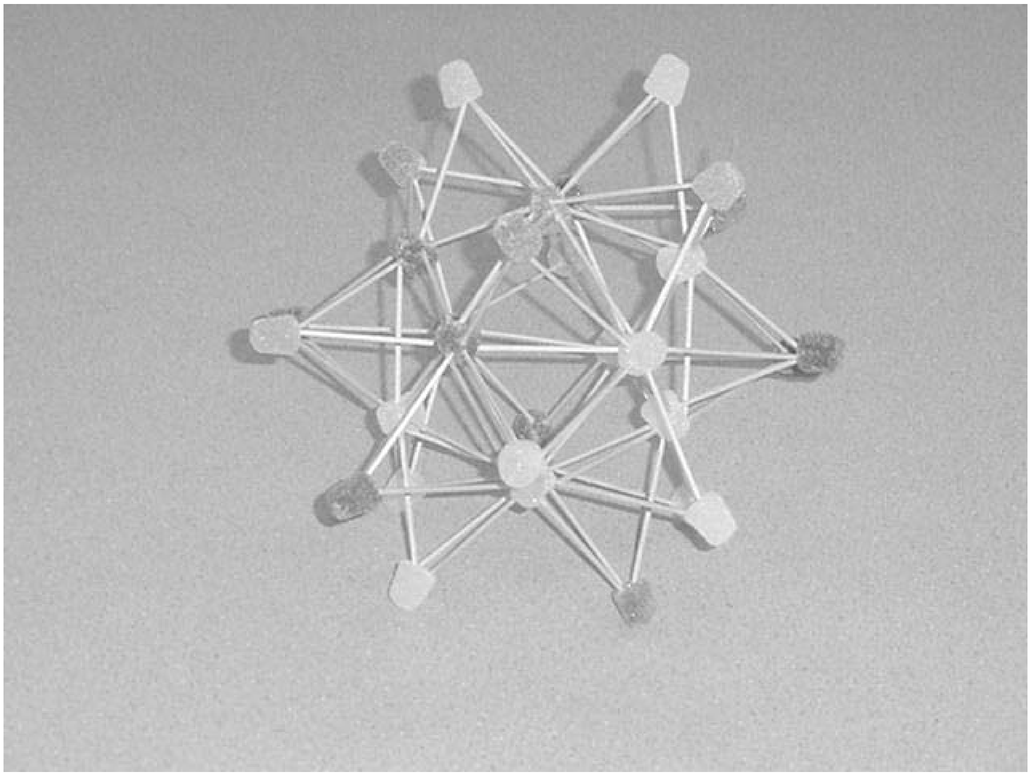
Picture 15

Accumulated Dust on Fan Blades

Picture 16

Birds Nests on Univent near Air Diffuser

Picture 17



Candy Gum Drops Used for School Projects

Fall Brook School **Indoor Air Results**

25 DeCicco Drive, Leominster, MA 01453 **Table 1** **Date: 06/03/2005**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
background		80	28	429	2	ND	31				
nurse	0	75	43	945	1	ND	50	Y # open: 0 # total: 3	N	N	Hallway DO, window-mounted AC, AP, near parking lot.
computer	0	75	45	504	1	ND	23	Y # open: 0 # total: 4	Y univent furniture plant(s)	N	Dust, plants, near parking lot.
gym	0	77	38	407	1	ND	21	Y # open: 0 # total: 3	Y ceiling	Y wall items dust/debris	Hallway DO,
art	1	77	40	458	ND	ND	22	Y # open: 2 # total: 4	Y univent plant(s)	N	Hallway DO, DEM, PF, TB.
music	1	78	41	528	ND	ND	25	Y # open: 2 # total: 4	Y univent	Y wall (weak)	Hallway DO, DEM.

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
Vice Principal	1	77	47	728	ND	ND	32	Y # open: 1 # total: 2	N	N	Hallway DO, Inter-room DO, window-mounted AC,
Principal	2	77	46	692	ND	ND	37	N # open: 0 # total: 0			Hallway DO, Inter-room DO.
cafeteria	200	78	43	664	1	ND	32	Y # open: 0 # total: 10	Y ceiling	Y wall (weak)	Hallway DO,
office	6	78	46	761	ND	ND	35	Y # open: 3 # total: 5	N	N	Hallway DO, PC.
computer (18)	0	77	35	754	1	ND	18	Y # open: 0 # total: 4	Y univent (off)	Y wall (off)	DEM, 28 computers.
1	0	77	43	619	1	ND	26	Y # open: 2 # total: 4	Y univent	Y wall (weak)	Hallway DO, DEM, PF, TB, cleaners.

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									Supply	Exhaust	
2	0	78	43	588	1	ND	27	Y # open: 2 # total: 4	Y univent	Y wall boxes items furniture	Hallway DO, #WD-CT: 12, DEM, PF, cleaners.
3	0	78	43	671	1	ND	23	Y # open: 1 # total: 4	Y univent boxes furniture plant(s)	Y wall (weak) boxes furniture	Hallway DO, #WD-CT: 2, breach sink/counter, DEM, PF, cleaners, items.
4	0	78	43	642	1	ND	23	Y # open: 2 # total: 4	Y univent	Y wall (off) boxes furniture	Hallway DO, #WD-CT: 2, DEM, aqua/terra, cleaners, plants.
5	0	78	42	629	1	ND	24	Y # open: 3 # total: 4	Y univent items furniture	Y wall	Hallway DO, #WD-CT: 4, AP, DEM, TB.

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Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

Fall Brook School **Indoor Air Results**

25 DeCicco Drive, Leominster, MA 01453 **Table 1** **Date: 06/03/2005**

Location/ Room	Occupants in Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (ppm)	Carbon Monoxide (ppm)	TVOCs (ppm)	PM2.5 (µg/m3)	Windows Openable	Ventilation		Remarks
									Supply	Exhaust	
6	0	78	43	556	1	ND	22	Y # open: 2 # total: 4	Y univent	Y wall	Inter-room DO, DEM, PF, aqua/terra.
7	23	78	42	593	1	ND	25	Y # open: 3 # total: 4	Y univent furniture	Y wall	Hallway DO, DEM, TB, nests, nests on UV, occupants gone 5 min.
8	15	78	44	647	1	ND	27	Y # open: 1 # total: 4	Y univent items furniture	Y wall	Hallway DO, #WD-CT: 4, DEM, musty odors from rotting food.
9	20	77	42	686	1	ND	25	Y # open: 0 # total: 2	Y univent	Y wall boxes furniture	Hallway DO, TB.
10	20	78	44	651	1	ND	27	Y # open: 2 # total: 2	Y univent items furniture	Y wall	Hallway DO, DEM, cleaners, items, plants.

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									Supply	Exhaust	
11	16	77	44	788	1	ND	26	Y # open: 0 # total: 2	Y univent items furniture	Y wall boxes furniture	Breach sink/counter, DEM, cleaners, items.
12	25	78	45	624	1	ND	29	Y # open: 2 # total: 2	Y univent boxes items furniture	Y wall boxes furniture	Hallway DO, CD, DEM, TB, cleaners, near parking lot.
13	21	78	44	807	1	ND	28	Y # open: 0 # total: 2	Y univent boxes furniture	Y wall (weak)	CD, DEM, TB, items, butterfly cages.
14	15	78	43	583	1	ND	29	Y # open: 2 # total: 2	Y univent boxes items furniture	Y wall (weak)	breach sink/counter, AD, DEM, PF.

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15	12	78	46	730	1	ND	31	Y # open: 2 # total: 2	Y univent items furniture	Y wall (weak)	Breach sink/counter, DEM, TB, cleaners.
17	18	77	42	774	ND	ND	26	Y # open: 1 # total: 4	Y univent (off)	Y wall (weak)	Hallway DO, DEM, plants.
19	24	77	42	692	1	ND	22	Y # open: 0 # total: 4	Y univent	Y wall (off)	Hallway DO, DEM.
20	0	79	41	644	1	ND	24	Y # open: 2 # total: 4	Y univent boxes items furniture	Y wall	Hallway DO, DEM, PF.
21	24	78	40	569	1	ND	22	Y # open: 2 # total: 4	Y univent boxes furniture	Y wall	DEM, PF, items.

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									Supply	Exhaust	
22	18	79	41	683	1	ND	25	Y # open: 2 # total: 4	Y univent items furniture	Y wall	Hallway DO, DEM, PF.
23	21	79	44	970	ND	ND	23	Y # open: 0 # total: 4	Y univent (off) plant(s)	Y wall	Hallway DO, DEM, PF, TB.
24	0	78	41	669	ND	ND	21	N # open: 0 # total: 0	Y univent	Y wall	#WD-CT: 5, DEM, PF, TB, cleaners.
25	14	79	45	1206	1	ND	21	Y # open: 0 # total: 4	Y univent boxes furniture	Y wall boxes furniture	DEM, PF, cleaners.
26	24	78	41	660	ND	ND	21	Y # open: 0 # total: 4	Y univent boxes items furniture	Y wall items	breach sink/counter, DEM, PF.

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									Supply	Exhaust	
27	15	78	39	647	ND	ND	26	Y # open: 2 # total: 4	Y univent (off)	Y wall boxes furniture	Inter-room DO, DEM, PF, TB, cleaners.
28	12	78	40	662	ND	ND	23	Y # open: 2 # total: 4	Y univent	Y wall	Hallway DO, DEM, TB.
29	17	78	39	607	ND	ND	24	Y # open: 2 # total: 4	Y univent plant(s)	Y wall	Hallway DO, Inter-room DO, DEM, PF, TB, cleaners, plants over UV.
30	18	79	42	774	ND	ND	18	Y # open: 2 # total: 4	Y univent	Y wall boxes furniture	DEM, PF, TB, aqua/terra, plants, terrarium near UV.
32	7	78	40	563	1	ND	22	Y # open: 2 # total: 4	Y univent (off)	Y wall	Hallway DO, #WD-CT: 8, #MT/AT: 1, DEM, PF, PS, plants.

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